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Published in:
Physics Letters B

DOI:
[10.1016/0370-2693\(81\)90234-3](https://doi.org/10.1016/0370-2693(81)90234-3)

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
1981

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Siemssen, RH., Jones, WP., Jacobs, WW., Foster, CC., Miller, DW., Saber, M., & Soga, F. (1981). On the “missing” deep-hole strength in 115Sn. *Physics Letters B*, 103(4-5), 323-325. [https://doi.org/10.1016/0370-2693\(81\)90234-3](https://doi.org/10.1016/0370-2693(81)90234-3)

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ON THE "MISSING" DEEP-HOLE STRENGTH IN ^{115}Sn [☆]

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Received 20 April 1981

Evidence is found for a "new" deep hole component in ^{115}Sn extending to about 18 MeV excitation and containing most likely $1f_{5/2}$ strength in addition to $2p$ strength. With this new component, a better definition of the "background" is possible. All of the combined $1g_{9/2}$, $2p_{1/2}$, $2p_{3/2}$ sum rule strength can be accounted for with the inclusion of the new component and the additional overall strength due to the reduced background.

Pickup of nucleons from the next inner shell from that of the valence nucleons has by now been observed on a wide range of nuclei [1–3]. In medium weight and heavy nuclei these deep-hole states manifest themselves as a giant resonance-like gross structure in which the hole strength is spread over many states [4]. A question of continuing interest is the location and determination of the strengths from the various subshells. For neutron pickup, typically no more than 50 percent of the total sum-rule strength of the deeply-bound orbitals has been found. Recently, however, proton pickup studies of deeply-bound hole states have been shown to exhaust the shell-model strength [5]. The whereabouts of the "missing" neutron hole strength is a topic of much concern and of central importance for the understanding of the deep-hole states.

Probably the most extensively studied nuclei in this respect are the odd- A isotopes of tin and in particular ^{115}Sn , for which the deeply-bound hole states have been investigated with different pick-up reactions [(p, d), (d, t) and (^3He , α)], and with high

as well as with moderate resolution [5–10]. In a study of the $^{116}\text{Sn}(d, t)^{115}\text{Sn}$ reaction at $E_d = 50$ MeV by Van der Werf et al. [7], about 45 percent of the combined $1g_{9/2}$, $2p_{1/2}$, $2p_{3/2}$ and $1f_{5/2}$ hole strength was found to reside in the gross structure below about 12 MeV excitation energy. As was also observed by these authors, more than the total sum-rule strength can be obtained if it is assumed that the continuous "background" on which the gross structure is riding is due to pick-up from inner shells. A similar conclusion was reached by Ishimatsu et al. [11], who did not subtract any background. On the other hand, there are no a priori criteria to determine which part, if any, of the background is due to pick-up. A reasonable approach to determine the background is thus to extrapolate it to low excitation energies from high excitation energies, where pick-up is thought to be unimportant [7]. In a high-resolution (d, t) study, Berrier-Ronsin et al. [8] observed about one half the inner hole strength of Van der Werf et al. [7] in those regions of excitation for which the data were overlapping. However, a more recent investigation by these same authors [10] has yielded results in better agreement with ref. [7].

In the present letter we report on the observation of a "new" deep-hole component in ^{115}Sn extending

[☆] Work supported in part by the National Science Foundation.

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to higher excitation energies than has been previously studied. In addition to containing additional hole strength the new component leads to a better definition of (and hence a reduction of) the background under the previously observed gross structure peaks, and thus to an increase in the extracted cross sections of the pick-up from the inner shells. With the identification of this new component and the accompanying reduction in background, all of the $1g_{9/2}$, $2p_{1/2}$, $2p_{3/2}$ and $1f_{5/2}$ subshell strength can be experimentally accounted for in ^{115}Sn .

In order to facilitate comparison with the $^{116}\text{Sn}(d, t)^{115}\text{Sn}$ data of Van der Werf et al. [7], a bombarding energy of 50 MeV was chosen for the present study. Polarized deuterons from an atomic-beam source were accelerated through the IUCF injector and main cyclotrons and were focussed on target in the multi-purpose 162 cm diameter scattering chamber. The resulting measurements of the (\vec{d}, t) and $(\vec{d}, ^3\text{He})$ analyzing powers will be reported in a separate article [12]. For the discussion here, differential cross sections were obtained by adding the normalized spin-up and spin-down data. The absolute normalization was derived by comparing the cross sections for the low-lying excited states in ^{115}Sn with those of Van der Werf et al. [7]. Tritons were detected by silicon surface barrier detectors and identified in two counter telescopes placed at opposite sides of the beam. The targets were rolled foils of thickness $\approx 1\text{--}2$ mg/cm² of enriched ($\geq 98\%$) metallic ^{116}Sn . An overall energy resolution of ≈ 120 keV was achieved.

A spectrum of the $^{116}\text{Sn}(d, t)^{115}\text{Sn}$ reaction at 15° is shown in fig. 1. In addition to the previously-observed gross structure denoted as areas II, III and IV, a very distinct shoulder (area V) is seen that extends out to about 18 MeV. This latter region is most likely to be due to $1f_{5/2}$ pick-up with some p strength in addition. To analyze the data we have taken slices as indicated in the figure. This method differs from that employed in ref. [7] in which gaussians of different widths were fitted to the gross structure. To separate areas II and III a smooth envelope was drawn through the data with the help of computer graphics. The "background" for a given spectrum was deduced from area VI and taken to be independent of excitation energy as indicated in fig. 1. This background was subtracted from the total peak areas, in constant proportions to that in region VI, to obtain the areas I

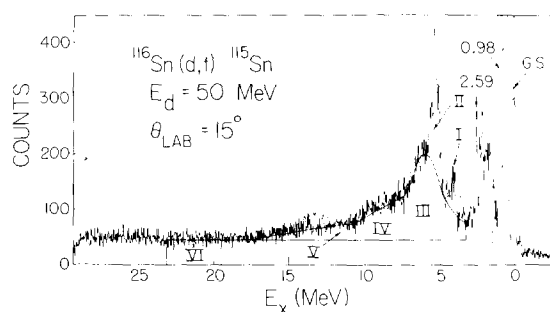


Fig. 1. Triton spectra from the $^{116}\text{Sn}(d, t)^{115}\text{Sn}$ reaction measured at 15° . The areas I through VI show the division of the gross structure into different parts as discussed in the next. The background level determined in region VI was taken to be constant with excitation energy, as indicated by the straight line drawn under regions I through V.

through V. The background deduced in this manner is about 40 percent lower than that taken in previous investigations, covering a smaller excitation region, in which it was assumed that area V was part of the background.

Differential cross sections for areas II–V and the "background" are shown in fig. 2 together with DWBA calculations performed with the program DWUCK IV [13]. The optical model parameters employed in these calculations are those of ref. [7]. The curves were obtained by limiting the possible combinations of l -transfers to two: a mixture of $l = 1$ and 4 and a mixture of $l = 1$ and 3. Except for area II the angular distributions do not allow one to distinguish between an $l = 3$ versus an $l = 4$ admixture to the $l = 1$ distribution. Tanaka et al. [9], however, have identified regions III and IV as $l = 4$ and we have therefore adopted this assignment. With these prescriptions, all of the $g_{9/2}$ hole strength is exhausted in areas II, III and IV (see table 1), while area V can account for the entire $f_{5/2}$ hole strength. Moreover, areas II–V exhaust the total $2p_{1/2}$ and $2p_{3/2}$ hole strength.

The $^{116}\text{Sn}(d, t)^{115}\text{Sn}$ data in the present investigation have been analyzed by dividing the spectra into the indicated energy bins. The observation of distinct shoulders (fig. 1) is suggestive of underlying broad, gaussian-like peaks with different widths: this was the basis for the decomposition of the gross structure in ref. [7]. Adopting this procedure here, we obtain for the $1f_{5/2}$ hole-state component a peak centered at

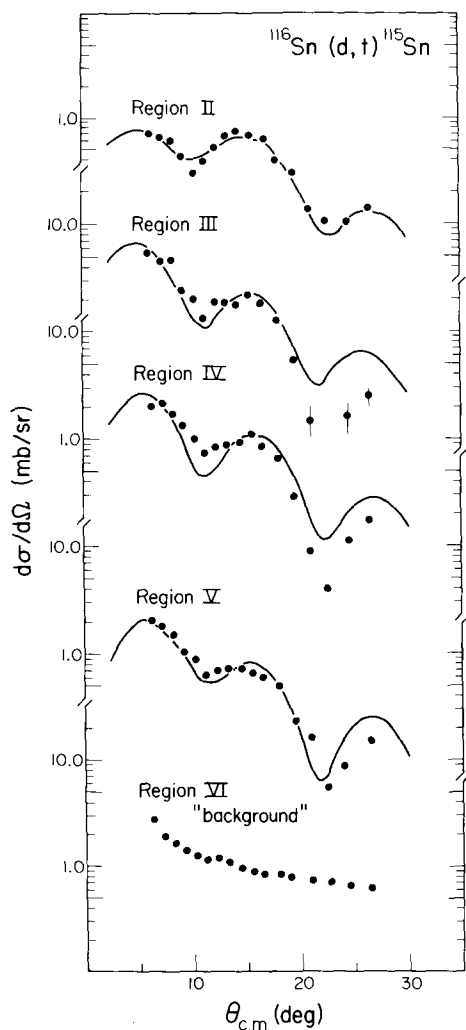


Fig. 2. Angular distributions of the gross structure and "background" decomposed into different areas as indicated in fig. 1. The curves are the result of DWBA calculations described in the text with l -transfer strengths as indicated in table 1.

10.6 MeV with a width of ≈ 8 MeV (FWHM), indicating a very large spreading width. The unperturbed $1g_{9/2}$ hole state (centroid energy) is located at 6.6 MeV [7]. The energy separation between $1g_{9/2}$ and $1f_{5/2}$ is thus about 4 MeV, which is to be compared with a separation of 3 MeV as calculated by Veje [14]. The same calculation would predict the $1f_{7/2}$ – $1f_{5/2}$ spacing to be about the same as the $1g_{9/2}$ – $1f_{5/2}$ spacing. Since the intrinsic DWBA cross section very rapidly decreases with more negative Q -value, it would

Table 1

Properties of individual states and of gross structure peaks observed in the $^{116}\text{Sn}(d,t)^{115}\text{Sn}$ reaction corresponding to pickup from inner shells.

E_x (MeV)	Area	$\Sigma C_i^2 S_i^{(a)}$		
		$l = 1$	$l = 3$	$l = 4$
2.59		0.22 ^{b)}		
3.65				0.14 ^{b)}
4.20	I	0.20 ^{b)}		
5.20	II	0.17 ± 0.04		
6.0	III	2.0 ± 0.2		
8.5	IV	1.2 ± 0.3		
12.0	V	1.9 ± 0.4	8.6 ± 1.4	
				2.15 ± 0.13
				4.6 ± 1.0
				4.0 ± 0.7

a) For $l = 3$, $1f_{5/2}$ and for $l = 4$ $1g_{9/2}$ pickup was assumed. For $l = 1$ transitions, spectroscopic factors obtained for $2p_{1/2}$ and $2p_{3/2}$ pickup were averaged.

b) From ref. [7].

be of interest to pursue these investigations at a higher bombarding energy where the Q -dependence is less dramatic, and one might also expect smaller cross sections for the background. Perhaps then, even deeper lying hole-state structures could be observed.

In summary, we have obtained evidence for a new deep-hole component in ^{115}Sn which is centered around 11 MeV in excitation energy and which most likely is due to the $1f_{5/2}$ hole-state. With this new component the total $1g_{9/2}$, $2p_{1/2}$, $2p_{3/2}$ and $1f_{5/2}$ neutron hole strength can be accounted for.

- [1] M. Sakai and K.I. Kubo, Nucl. Phys. A185 (1972) 217.
- [2] T. Ishimatsu et al., Nucl. Phys. A185 (1972) 273.
- [3] For a recent review, see: G.M. Crawley, Inst. Phys. Conf. Ser. No. 49 (1980) p. 127; Proc. Intern Symp. on Highly excited states in nuclear reactions (Osaka, 1980) p. 590.
- [4] S.Y. van der Werf et al., Phys. Rev. Lett. 33 (1974) 712.
- [5] A. Stuirbrink et al., Z. Phys. A297 (1980) 307.
- [6] M. Sekiguchi, Y. Shida, F. Soga, Y. Hirao and M. Sakai, Nucl. Phys. A278 (1977) 231.
- [7] S.Y. van der Werf, M.N. Harakeh, L.W. Put, O. Scholten and R.H. Siemssen, Nucl. Phys. A289 (1977) 141.
- [8] G. Berrier-Ronsin et al., Phys. Lett. 67B (1977) 16.
- [9] M. Tanaka et al., Phys. Lett. 78B (1978) 221.
- [10] E. Gerlic et al., Phys. Rev. C21 (1980) 124.
- [11] T. Ishimatsu, M. Niwano, N. Kawamura, H. Ohmura and T. Awaga, Nucl. Phys. A336 (1980) 205.
- [12] R.H. Siemssen et al., to be published.
- [13] P.D. Kunz, Program DWUCK IV, unpublished.
- [14] C.J. Veje, in: Nuclear structure, Vol. 1, eds. A. Bohr and B.R. Mottelson (Benjamin, New York, 1969) p. 239.